Beyond the Local Void: A comprehensive view on the origins of the Amaterasu particle

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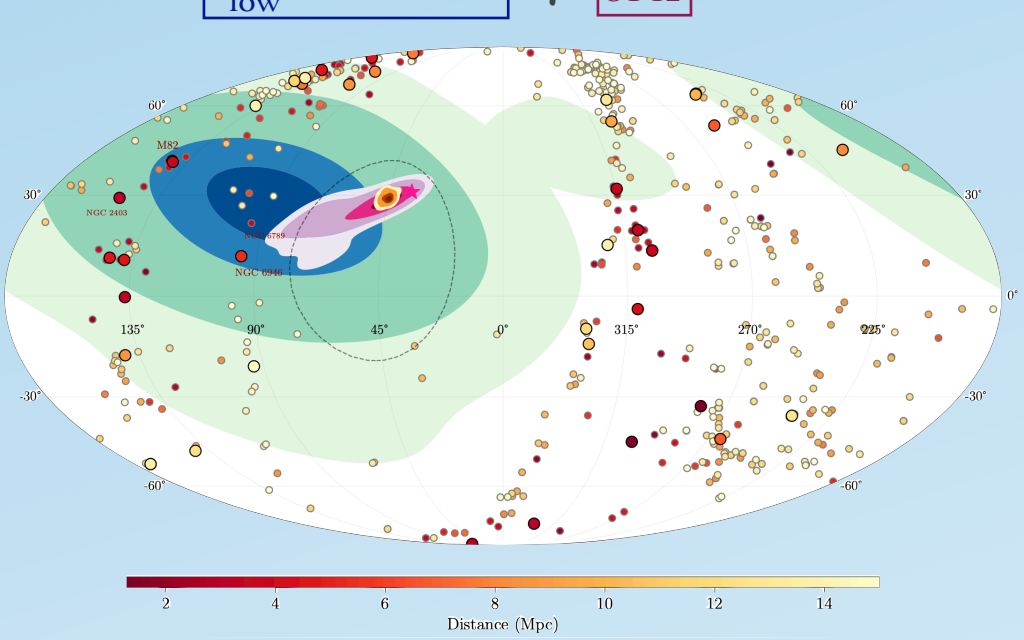
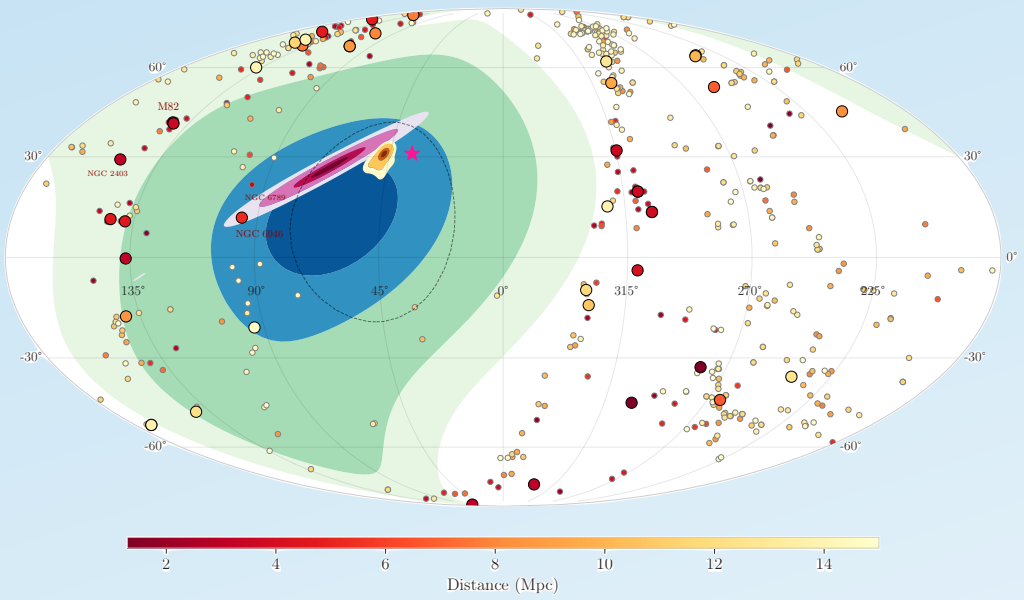
Individual particles at the highest energies:

- Events at the highest energies have the potential to be the most constraining, higher energies suggest closer horizons and trajectories that are less impacted by magnetic fields.
- Amaterasu is the second highest energy particle ever detected, $E_{\rm det} = (244 \pm 29\,(stat.)^{+51}_{-76}(syst.))$ EeV [1], its arrival direction aligns with the Local Void.

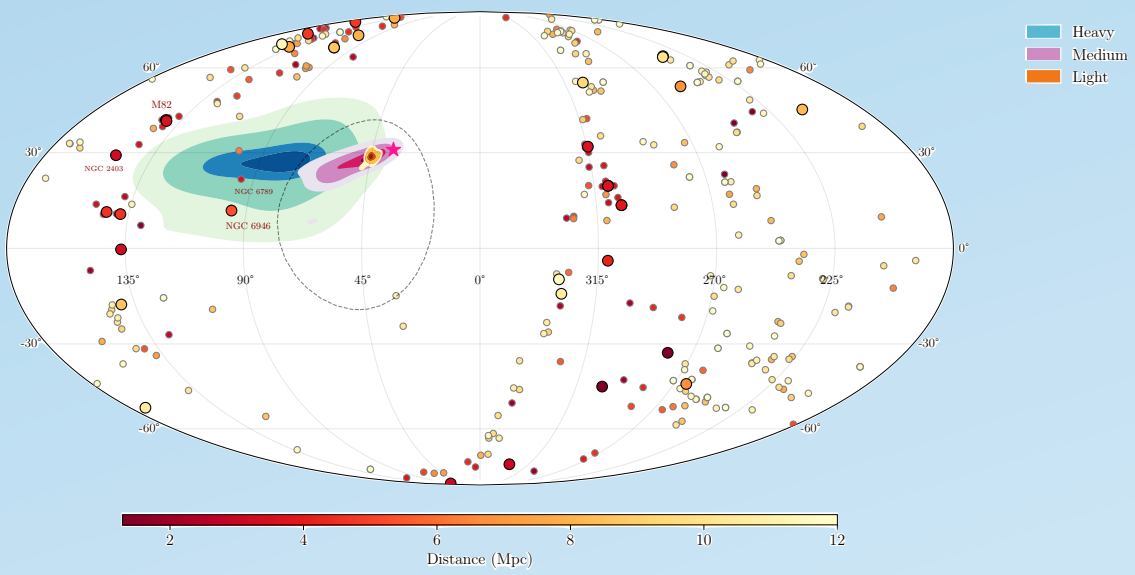
$E_{\rm low} = 168 \pm 29$ EeV + JF12



$E_{\rm low} = 168 \pm 29$ EeV + UF23



$E_{\rm nom} = 244 \pm 29$ EeV + JF12



Methods:

- We use CRPropa3 [2] to simulate the propagation of UHECRs, including energy losses and magnetic fields.
- We make two analyses, one with the nominal energy, E_{nom} and one where we include the lower bound of the systematic uncertainty, E_{low}.
- We use Approximate Bayesian Computation, a simulation based inference method, to estimate the posterior distribution of our six free parameters: $B_{\rm rms}$, $L_{\rm C}$ of the extra-Galactic magnetic field and $D_{\rm src}$, $E_{\rm src}$ and $(l, b)_{\rm src}$.
- We define a deviation $d = |X_{\rm sim} - X_{\rm exp}|$ and a tolerance $\epsilon = 3\sigma$, events that satisfy $|E_{\rm sim} - E_{\rm exp}| \leq 3\sigma$ and $|dir_{\rm sim} - dir_{\rm exp}| \leq 3\sigma$ are accepted.

Results:

- We use four galaxy catalogs [3,4,5,8] including star-burst galaxies, active galactic nuclei and regular galaxies to check for overlaps.
- We find that the source should be at $D_{\rm src} \leq 12$ Mpc for E_{nom} and $D_{\rm src} \leq 15$ Mpc for E_{low}.
- Our results are dependent on the Galactic magnetic field model we use, JF12[7] and UF23[10].

Conclusion:

- Our results are consistent with region of space beyond the Local Void, especially when considering the systematic uncertainty and the arrival compositon.
- We find multiple possible sources, including several star-burst galaxies, like M82.

References:

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